

# A METHOD FOR PROGRAMMING AND ERASING AN NROM CELL

## TECHNICAL FIELD OF THE INVENTION

[0001] The present invention relates generally to memory devices and in particular the present invention relates to programming and erasing nitride read only memory cells.

## BACKGROUND OF THE INVENTION

[0002] Memory devices are typically provided as internal storage areas in the computer. The term memory identifies data storage that comes in the form of integrated circuit chips. In general, memory devices contain an array of memory cells for storing data, and row and column decoder circuits coupled to the array of memory cells for accessing the array of memory cells in response to an external address.

[0003] There are several different types of memory such as random access memory (RAM) and read only memory (ROM). RAM is typically used as main memory in a computer environment. One can repeatedly read data from and write data into RAM. Most RAM is volatile, which means that it requires a steady flow of electricity to maintain its contents. When the power is turned off, the data in RAM is lost.

[0004] This is in contrast to ROM that generally only permits the user to read data already stored in the ROM but the ROM retains data after power is removed (i.e., non-volatile). Computers almost always contain a small amount of ROM that holds instructions for starting up the computer. Unlike RAM, ROM generally cannot be written to in routine operation.

[0005] Yet another type of non-volatile memory is flash memory. A flash memory is a type of EEPROM that can be erased and reprogrammed in blocks instead of one byte at a time. Many modern PCs have their BIOS stored on a flash memory chip so that it can easily be updated if necessary. Flash memory is also popular in modems because it enables the modem manufacturer to support new protocols as they become standardized.

[0006] Another type of non-volatile memory is a nitride read only memory (NROM). NROM has some of the characteristics of flash memory but does not require the special

fabrication processes of flash memory. NROM can be implemented using a standard CMOS process.

**[0007]** Because of NROM's CMOS process, the NROM can be embedded into other architectures, such as microcontrollers, that also use the CMOS process. However, one problem with embedding the NROM is that an NROM memory array, susceptible for embedding, requires high current consumption for program and erase.

**[0008]** For the reasons stated above, and for other reasons stated below which will become apparent to those skilled in the art upon reading and understanding the present specification, there is a need in the art for a way to erase NROM arrays without being over-erased.

## SUMMARY

**[0009]** The above-mentioned problems with programming and erasing NROM arrays and other problems are addressed by the present invention and will be understood by reading and studying the following specification.

**[0010]** The various embodiments relate to programming and erasing NROM cells. In one embodiment, these cells are embedded in CMOS integrated circuits. One embodiment for programming an NROM cell includes applying a ramp voltage to a gate input. A constant voltage is applied to one of the two source/drain regions. The remaining source/drain region is coupled to ground potential.

**[0011]** One embodiment for erasing an NROM cell includes applying a constant voltage to the gate input. A constant positive current is sourced to one of the source/drain regions. The remaining source/drain region is allowed to either float, coupled to ground, or is coupled to the first source/drain region, depending on the embodiment.

**[0012]** In another embodiment, the erase operation includes applying a constant voltage to one of the source/drain regions. A negatively ramped voltage is coupled to the gate input and the remaining source/drain region is coupled to ground, allowed to float, or coupled to the first source/drain region, depending on the embodiment.

**[0013]** Further embodiments of the invention include methods and apparatus of varying scope.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0014]** Figures 1A and B show diagrams of an NROM memory cell of the present invention.

**[0015]** Figure 2 shows a circuit equivalent for the program operation in the NROM memory cell in accordance with Figure 1.

**[0016]** Figure 3 shows a flow chart of a method for programming an NROM memory cell in accordance with one embodiment of the present invention.

**[0017]** Figure 4 shows a flow chart of a method for erasing an NROM memory cell in accordance with one embodiment of the present invention.

**[0018]** Figure 5 shows a flow chart of a method for erasing an NROM memory cell in accordance with an alternate embodiment of the present invention.

**[0019]** Figure 6 shows a block diagram of one embodiment of a system of the present invention having an embedded NROM array.

### **DETAILED DESCRIPTION**

**[0020]** In the following detailed description of the invention, reference is made to the accompanying drawings that form a part hereof, and in which is shown, by way of illustration, specific embodiments in which the invention may be practiced. In the drawings, like numerals describe substantially similar components throughout the several views. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention. Other embodiments may be utilized and structural, logical, and electrical changes may be made without departing from the scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the appended claims and equivalents thereof.

**[0021]** Figures 1A and 1B illustrate a diagram of an NROM memory cell of the present invention. This cell is comprised of a control gate 100 formed on top of an oxide layer 101. Below the oxide layer is a layer of nitride 103 upon which the charge is stored for the various states of the cell. In one embodiment, the cell has areas 105 and 106 for storing two bits of data on the nitride 103. The nitride 103 can be patterned either in isolated patches matching the individual cells (as in Figure 1A) or as a continuous blanket covering a whole unit of memory array (as in Figure 1B).

**[0022]** Two source/drain regions 109 and 111 are at either end of the gate 100. The source/drain regions 109 and 111 are connected by a channel area 110 between the two regions 109 and 111. The function of each source/drain region 109 or 111 (i.e., whether source or drain) depends upon which bit area 105 or 106 is being read or written. For example, in a read operation, if the carrier is input at the left side source/drain region 111 and output from the right side region 109, the left side is the source 111 and the right side is the drain 109 and the data bit charge is stored on the nitride 103 at the source end 111 for bit area 106.

**[0023]** Figure 2 illustrates a circuit that models the NROM memory cell of Figure 1. This circuit is comprised of a capacitor 201 coupled through a node 203 to a resistor 202. This model will be referred to subsequently with reference to the programming method of Figure 3.

**[0024]** Standard long-channel NROM cells for double-bit storage are inherently insensitive to over-erasure. The threshold voltage for such a cell in an erased state is kept at its “neutral” value by the mid-channel region away from either source/drain region, which has no holes trapped in the nitride dielectric above.

**[0025]** A newer type of short-channel NROM cells forgoes the double-bit storage in exchange for programming at a lower voltage. Such cell structure and operation are particularly well suited for embedded memory applications. These short-channel NROM cells can inject hot holes in the mid-channel region during an erase operation and thus become sensitive to over-erasure like traditional stack-gate flash memory. The methods of

the present invention are applicable to both long channel (double-bit) and short channel (single-bit) architectures.

[0026] One problem with embedding an NROM memory array in another CMOS device is that the NROM memory array typically requires 10V and a high programming current. This could potentially damage the other circuitry in the device in which the NROM is embedded.

Figures 3 – 5, as discussed subsequently, illustrate the various methods for programming and erasing of the present invention. The order of the steps is for illustration purposes only. It is preferred that all voltages be applied and developed simultaneously. However, alternate embodiments may use one or more sequential steps in applying the voltages.

[0027] Figure 3 illustrates a flow chart of a method for programming an NROM memory array in accordance with one embodiment of the present invention. This method does not require either a high constant voltage or a high programming current.

[0028] The source region is at ground potential 301 when a voltage in the range of 3.0 to 6V is applied to the drain region 305. Alternate embodiments use other voltages on these connections. For example, in one embodiment, the source may have a reverse source to body voltage applied.

[0029] A linear ramp voltage is applied to the control gate of the cell 307. In one embodiment, this voltage starts in the range of 0 to 6V and goes up to 4 to 12V for a time in the range of 0.001 – 1 millisecond. In one embodiment, the ramp voltage starts at 5V and goes up to 10V. Alternate embodiments use other ranges for the voltages and the time.

[0030] Using the method of Figure 3 to the circuit of Figure 2, the ramp voltage is applied to the capacitor 201. The voltage at the node 203 ramps up to a certain point then levels off. This point is where the displacement current of the capacitor 201 equals the conduction current of the resistor 202. This constant voltage maintains the constant current for programming the memory array while the input voltage ramps up.

[0031] Figure 4 illustrates a flow chart of a method for erasing an NROM memory array in accordance with one embodiment of the present invention. This method applies a

constant gate voltage 401 in the range of 0 to -12V. In one embodiment, the gate voltage is approximately -7V.

[0032] One of the source/drain regions can remain floating, grounded, or tied to the other source/drain region 403. The other drain/source region has a constant positive current applied 405.

[0033] The injected constant current is in the range of gate induced drain leakage (GIDL) of 0.1 nA to 10  $\mu$ A per cell in the NROM array. These voltages, in one embodiment, are applied for a time in the range of 1  $\mu$ s to 1 second. Alternate embodiments use other ranges of time.

[0034] In an alternate embodiment, the voltage that the forced current develops on the drain/source region 405 can be monitored. The erase operation can then be ended when this voltage reaches a predetermined voltage. This voltage threshold can be set to any value in correlation with the dynamics of the erase operation for the NROM cells.

[0035] Figure 5 illustrates a flow chart of an alternate embodiment method of the present invention for erasing an NROM memory array. This method applies a constant voltage on one of the source/drain regions 501. The other drain/source region remains floating, grounded, or biased with the same voltage as the first source/drain region 503. The gate has a negatively ramped voltage applied 505. In one embodiment, this voltage is in the range of 0 to -4V and goes down to -7 to -12.

[0036] By ramping the gate voltage, the erase method of Figure 5 can perform an erase operation with less drain current consumption than a prior art erase operation. This can reduce the overall power requirements of the device into which the NROM array is embedded.

[0037] In the methods of Figures 3 – 5, the erase operation would proceed at a more constant pace than in a prior art erase operation with constant voltages. Additionally, the current absorbed by the array would be uniform in time and lower for the methods of the present invention than at the beginning of an erase pulse in the prior art method. The GIDL

and the rate of charge trapping in the oxide-nitride-oxide dielectric remain constant throughout the time of the erase operation.

[0038] Figure 6 illustrates a block diagram of a system in which an NROM array is embedded. This system is comprised of a microprocessor 601 and the NROM array 602. These components 601 and 602 are incorporated onto a single integrated circuit die. Alternate embodiments may add additional components such as input/output circuitry and other types of memory.

## CONCLUSION

[0039] The methods of the present invention for programming and erasing an embedded NROM array operate effectively on both long-channel and short-channel cells. These methods provide a means for programming and erasing while maintaining a constant programming and erase current at lower voltages. This decreases power consumption and increases the reliability, thus decreasing the failure rate, of the device.

[0040] Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that any arrangement that is calculated to achieve the same purpose may be substituted for the specific embodiments shown. Many adaptations of the invention will be apparent to those of ordinary skill in the art. Accordingly, this application is intended to cover any adaptations or variations of the invention. It is manifestly intended that this invention be limited only by the following claims and equivalents thereof.